United States
Department of
Agriculture

Economic
Research
Service

Resources
and
Technology
Division

The U.S. Agricultural Resources Model (USARM)

Model Documentation

Kazim Konyar
Ian McCormick
Tim Osborn

The U.S. Agricultural Resources Model (USARM): Model Documentation, by Kazim Konyar, Ian McCormick, and Tim Osborn. Resources and Technology Division, Economic Research Service, U.S. Department of Agriculture. Staff Report No. AGES 9317.

Abstract

As part of its ongoing research into agricultural policy and natural resource use, the Resources and Technology Division of USDA's Economic Research Service developed the U.S. Agricultural Resources Model (USARM). This partial equilibrium, comparative static programming model provides estimates of effects on the location, production, and prices of principal crops, commodity program participation, and the use of agricultural inputs resulting from changes in resource constraints, prices, and policy parameters. This report documents USARM including model justification, description of model equations, and discussion of the method of calibration.

Keywords: Agricultural policy, mathematical programming, economic models.

1301 New York Avenue, NW.
Washington, DC 20005-4788

August 1993

Contents

Page

Introduction 1

Justification and General Description of USARM 1

USARM Equations 3

Demand Functions 8

Cost Functions and Model Calibration 9

Market Equilibrium under Government Intervention 12

References 14

Appendix: U.S. Agricultural Resources Model Code Written in GAMS . 16

The U.S. Agricultural Resources Model (USARM)

Model Documentation

Kazim Konyar
Ian McCormick
Tim Osborn

Introduction

This paper documents a mathematical programming model of the U.S. crop sector titled, "U.S. Agricultural Resources Model (USARM)." USARM is designed to estimate the effects of changes in Government agricultural commodity programs, input prices, and resource constraints on the location, production, and prices of principal crops, commodity program participation, and the use of agricultural inputs. The model was developed in the Resources and Technology Division (RTD), Economic Research Service (ERS), U.S. Department of Agriculture (USDA), and is one of the RTD's tools supporting ongoing research on agricultural policy and natural resource use.

Since its creation in 1989, USARM has been used to analyze the national and regional effects of the Conservation Reserve Program, Wetlands Reserve Program, greater commodity program flexibility, as well as other agricultural policy options (Konyar and McCormick, 1990; Ervin et al., 1991; Boyd, Konyar, and Uri, 1992; Ribaudo, Konyar, and Osborn, 1991). The model has gone through several revisions since its creation. Currently, it is based on 1990 production, price, and Government program data. The model will continue to be refined, improved, and updated to incorporate new data and the changing farm policy environment.

The next section gives a justification for developing USARM and a general description of the model. The following section describes the model equations and the method of model calibration. The appendix contains the full model as it is programmed in the General Algebraic Modeling System (GAMS).

Justification and General Description of USARM

The Federal Government has intervened in agriculture at the individual farm level since 1933 with the stated intention of stabilizing commodity prices and supporting farm income. Over the years, commodity programs expanded and became more complex in order to deal with a multitude of policy issues ranging from increased commodity surpluses to the effect of agricultural practices on the environment. Furthermore, there is an increased emphasis by policymakers

on the need to achieve consistency among Federal farm programs. Also, there is the recognition that proposed legislation and programs should be fully assessed with respect to their impacts on crop production, budget outlays, export markets, and the environment, before they are enacted.

The complexities of the farm policy instruments, conflicting political and economic interests, and the multiobjective nature of policymaking necessitate the consideration of a large number of policy alternatives and their evaluation before an efficient policy is proposed. Efficiency, from the least-cost point of view, would require measuring the effect of policies on society's welfare. A highly sophisticated economic model is needed that can simulate market equilibrium under various policy options, capture the important linkages in the agricultural sector, keep track of the various policy objectives, and allow policymakers to make quantitative assessments of marginal changes in the existing institutions and the way those changes are implemented.

The model that can satisfy the above requirements must first simulate competitive equilibrium, in order to capture farm-firm behavior and calibrate exactly to a base year so that policy impacts can be assessed. The model should be regional in detail, in order to capture the heterogeneous nature of regional resource endowments and to keep track of the regional effects of policy changes on resource use and the environment. It should simultaneously account for changes in the acreage patterns of the major crops within regions and between regions. It must incorporate major policy instruments. The model has to treat farm program participants and nonparticipants separately so that Government farm program provisions can be fully integrated and their effects assessed. Furthermore, the model should endogenously determine market prices and deficiency payments so that policy effects on program outlays can be measured.

USARM was developed as a programming model to fulfill the need for a comprehensive policy assessment tool. Selecting a programming model for the policy analysis, instead of an econometric model, was necessitated for several reasons. Over the years, farm policies have been constantly changing and consequently there are no continuous and consistent historical data to econometrically estimate farmers' responses to policy changes. Furthermore, new policy instruments or new combinations of existing policy instruments are continually being introduced. There are no historical data on these new arrangements, however, so their likely impact on farmer behavior cannot be positively measured. Moreover, the need to assess the policy impacts at the regional level necessitates the measurement of farmers' responses at the regional level. Data at the regional level are even more scarce. In addition to the data problem, it is fairly difficult to econometrically model and simulate farmer behavior under resource and policy constraints. Under these circumstances mathematical programming is the best approach to modeling and analyzing the complexities of the U.S. agricultural sector.

USARM is constructed in a partial equilibrium, comparative static framework. The smallest decision-making unit is a region. There are 12 regions spanning the 48 contiguous States. A region may be defined as a State, however, as the raw data provide sufficient detail. Each region is modeled as an aggregate

farm allocating land to barley, corn, cotton, hay, oats, rice, sorghum, soybeans, wheat, and the Conservation Reserve Program (CRP). Farmers are assumed to make, simultaneously, a three-level decision: how many acres to allocate to various crops and CRP, how much of the acreage to put under government agricultural commodity programs, and how many acres to cultivate with and without irrigation. An activity, or a decision variable, is formed by a particular intersection of the above three decision sets.

Farmers are assumed to be profit-maximizers and the market equilibrium is simulated using this assumption. Profit for each activity is defined as the difference between a quadratic total revenue function and activity-specific quadratic total cost function. The model is calibrated to replicate observed base year harvested acreage and commodity market prices. Policy simulations are compared with the base year. A solution to the optimization problem provides measurements of the impacts of exogenous shocks, such as changes in agricultural commodity programs, resource constraints, resource prices, and commodity demand conditions on the location, production, and prices of the principal crops, resource use, Government program participation, and Government program costs. The model is solved using GAMS/MINOS computer software and the solution values are conditional near-term estimates of impacts from simulations.

USARM Equations

USARM encompasses 12 regions and 10 cropping activities, including the Conservation Reserve Program (CRP). The decision variable in each region is the amount of acreage allocated to an activity defined as the intersection of individual elements from the following choice sets: crop, irrigation or dryland cultivation, and participation or no participation in the Deficiency Payment Program. Definitions of indices, variables, and parameters used in the model are given in table 1. Table 2 shows the regions and the corresponding States.

The model is defined by the following objective function and constraints.

(1) Objective Function

$$\underset{X_{crig}}{Max\ CPS} = \sum_c (a_c + 0.5 b_c Q_c) \cdot Q_c + \sum_c [TP_c - (a_c + b_c Q_c)] \cdot Q_{cP}$$

$$+ [\sum_c \sum_r (rmp_{cr} - nmp_c)] \cdot [\sum_i \sum_g y_{crig} \cdot X_{crig}] - \sum_c \sum_r \sum_i \sum_g (d_{crig} + e_{crig} \cdot X_{crig}) \cdot X_{crig}$$

The objective function represents the maximization of aggregate producer and consumer welfare for all regions and activities. This formulation ensures a

Table 1--Definitions of indices, variables, and parameters

Indices		
c	Cropping choice	$c = 1, \ldots, 9$
r	Regions	$r = 1, \ldots, 12$
i	Irrigation practice	i = D (dryland), I (irrigated)
g	Support program status	g = P (in program), N (not in program)
Variables		
CPS	Consumer plus producer surplus	
Q_c	National aggregate crop output	
Q_{cP}	National aggregate crop output by program participants	
X_{crig}	Acreage	
Parameters		
a_c	Intercept of linear demand function	
b_c	Slope of linear demand function	
ϵ_c	Aggregate demand elasticity	
rmp_{cr}	Base year regional market price	
nmp_c	Base year national market price	
d_{crig}	Intercept of linear cost function	
e_{crig}	Slope of linear cost function	
$crprate_r$	Ratio of CRPBASE to CRP acreage of program participants	
$fail_{criP}$	Crop failure rate	
y_{criP}	Program yield	
y_{crig}	Actual yield	
arp_c	Acreage reduction ratio for program crops	
w_{crIg}	Water use rate (acre-feet/acre)	
AC_{crig}	Average cost (dollars/acre)	
$LAND_{ri}$	Total available cropland (1,000 acres)	
$MAXACRE_{cr}$	Maximum historical acreage (1,000 acres)	
$WATER_r$	Total available irrigation water (1,000 acre-feet)	
$BASE_{cr}$	Program crop base acreage (1,000 acres)	
$CRPBASE_r$	Base acreage deducted from program participants who are also in CRP (1,000 acres)	

Table 2--Definition of regions and corresponding States

Region	States included
Appalachian	Kentucky, North Carolina, Tennessee, Virginia, West Virginia
Corn Belt	Illinois, Indiana, Iowa, Missouri, Ohio
Delta States	Arkansas, Louisiana, Mississippi
Lake States	Michigan, Minnesota, Wisconsin
Northeast	Connecticut, Delaware, Maine, Maryland, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont
Northern Pacific	Oregon, Washington
Northern Mountain	Idaho, Montana, Wyoming
Northern Plains	Kansas, Nebraska, North Dakota, South Dakota
Southeast	Alabama, Florida, Georgia, South Carolina
Southern Mountain	Arizona, Colorado, Nevada, New Mexico, Utah
Southern Pacific	California
Southern Plains	Oklahoma, Texas

competitive equilibrium solution. The first expression in the objective function measures the area under crop-specific linear demand curves. With this formulation, crop prices are endogenously determined within the model.

The second expression accounts for the deficiency payments to the program participants. In this model, the only Federal support available to farmers is the support provided under the Deficiency Payment Program. Other programs such as Paid Land Diversion (PLD), the 50/92 or 0/92, Export Enhancement, Disaster Aid, and so forth, are excluded as these programs constitute a small portion of the support farmers receive under Government programs. Furthermore, some of these other programs are offered only in certain years.

The deficiency payment the participating farmers receive is the difference between the target price and the higher of the weighted average marketing price from the entire marketing year or the basic loan rate. In recent years, the loan rates have been intentionally kept just below the market prices. For this reason, loan rates are ignored and only the endogenously determined market price is used in deficiency payment calculations.

Crop market prices, and, therefore, deficiency payments are endogenously determined. Using the endogenously determined market prices in deficiency payments calculations, however, results in first-order conditions that are different from the desired optimality conditions. This problem is dealt with in the section below, "Market Equilibrium under Government Intervention."

The third expression captures the differences between national and regional market prices. For some regions, the difference may be a relatively large positive number, reflecting the region's distance from national markets. For some regions this expression may be negative.

The last expression in the objective function is the quadratic total cost per acre. The costs are quadratic in land only. The other inputs are modeled using Leontief technology. The derivation of the parameters of the cost functions and the exact calibration of the model are accomplished in the same step. The procedure is discussed below in the section, "Cost Functions and Model Calibration." Equation "PMPOBJEQ" in the appendix shows how the objective function is modeled in GAMS.

The objective function is subject to the following constraints.

(2) National aggregate crop output

$$Q_c = \sum_r \sum_i \sum_g y_{crig} \cdot X_{crig}$$

Each equation in this set defines crop specific national output as the sum of the products of actual yield and harvested acreage. Equation "TSUPPLYEQ" in the appendix shows the GAMS specification.

(3) National aggregate crop output by commodity program participants

$$Q_{cP} = \sum_i \sum_r y_{criP} \cdot fail_{criP} \cdot X_{criP}$$

Equations in this set calculate national aggregate crop output used in determining deficiency payments to farmers. The resulting output is different from the actual output. A provision of the Deficiency Payment Program requires that payments to farmers be based on program production rather than actual production levels. Program production is determined by multiplying program yield, a yield predetermined for each crop by the Agricultural Stabilization and Conservation Service (ASCS), by acreage planted. Harvested acreage, which is endogenously determined in the model, is converted to planted acreage by using a crop failure ratio, fail, a ratio of planted to harvested acreage. Equation "PSUPPLYEQ" in the Appendix shows the GAMS specification.

(4) **Land constraints**

$$\sum_{c}\sum_{g}\frac{1}{1-arp_{c}}\cdot X_{crig}\leq LAND_{ri}$$

A set of equations constrains the total irrigated and dryland acres in a given region to the actual base year irrigated and dryland acres in that region. This constraint also forces program participants to set aside a portion of their acreage for conserving use required under the Acreage Reduction Program, a companion to the Deficiency Payment Program. Part of the land to be idled for this purpose is determined by a crop-specific acreage reduction ratio (ARP). For example, if the ARP for a crop is 20 percent, then to cultivate 1 acre of that crop and receive deficiency payments, 1.25 acres of land is needed. The ARPs for the nonparticipants are equal to zero. Equations "DRYLAND" and "IRRLAND" in the appendix give the GAMS specification.

(5) **Maximum acreage constraints**

$$\sum_{i}\sum_{g}X_{crig}\leq MAXACRE_{cr}$$

Constraints defined by these equations require that total acres of a crop harvested in a region may not exceed the maximum historical acreage for that crop in that region. See the appendix equation "MAXACRES" for the GAMS specification.

(6) **Irrigation water constraints**

$$\sum_{c}\sum_{g}w_{crig}\cdot X_{crig}\leq WATER_{r}$$

Total irrigation water used by all activities in a region is constrained to be no greater than the amount of water farmers are currently using in that region. Given the decreasing availability of both surface and ground water, limiting the water use to current use levels is not too restrictive. Equation "WATER" in the appendix shows how this constraint is modeled in GAMS.

(7) **Commodity program crop base constraints**

$$\sum_{i}\frac{1}{1-arp_{c}}\cdot fail_{criP}\cdot X_{criP}\leq BASE_{cr}$$

A set of equations in this constraint group imposes the base acreage provisions of the Deficiency Payment Program. The mandate requires that, when allocating acreage to a crop and conserving use, the participating farmers are not to exceed the available established base acreage for that crop. The ASCS measures the base acreage and acreage diverted for conserving use in terms of

planted acreage. Activity levels in the model, however, are measured in terms of harvested acreage. To reconcile this discrepancy, the crop failure ratio is used. The constraints also impose another program provision that the program participants set aside part of their crop base for conserving use. The amount of land to be conserved is determined on the basis of actual acres planted under participation and the ARP ratio.

The base acreage stipulation of the Deficiency Payment Program allows farmers to combine the bases they own for barley and oats, and corn and sorghum. For example, a farmer who owns 100 acres of barley and oats base each can combine them and apply a total of 200 acres of base toward only one of the crops or plant the two crops in any acreage combination not exceeding 200 acres. Equations "BBAROAT," "BCORSOR," and "BREST" in the appendix show how this is accomplished in GAMS.

(8) Commodity program regional base constraints

$$\sum_c \sum_i \frac{1}{1-arp_c} \cdot fail_{criP} \cdot X_{criP} \leq \sum_c (BASE_{cr}) + CRPBASE_r - (crprate_r \cdot \sum_i X_{CRPriP})$$

Constraints defined by these equations dictate the base acreage provision of the Conservation Reserve Program. The provision states that farmers participating in CRP who also have base acreage must reduce their base by an amount calculated using a ratio of their CRP acreage to their cropland acreage. For this purpose a ratio, crprate, is constructed by dividing the base reduced by the deficiency payment recipients, who also have land in CRP, by their CRP acreage. Although this ratio is not identical to the ratio defined under the CRP rules, it is the only way the base reduction could be modeled and still produce the desired result. Farmers can use any base for this reduction and thus these constraints are not crop-specific but instead are summed over all program crops.

Demand Functions

Calculation of the crop specific linear demand function parameters is shown below. The parameters are calculated using national aggregate demand elasticities for each crop (ϵ) and the base year national market price (nmp^0) and quantity (Q^0).

$$b_c = \frac{nmp_c^0}{Q_c^0 \cdot \epsilon_c} \qquad a_c = nmp_c^0 - (b_c \cdot Q_c^0)$$

The parameter definitions for "BETA" and "ALPHA" in the appendix show the calculations in GAMS.

Cost Functions and Model Calibration

The basic theorem of linear programming implies that, in the solution, the number of nonzero activities must exactly equal the number of binding constraints. In the current model, there are nearly 1,000 nonzero activity levels but fewer constraints. Under these conditions, model solutions will result in fewer activities than actual. In order to produce model solutions that are close to the observed levels of the activities, the traditional linear programming models often resort to *ad hoc* constraints on resources and/or activity levels.

Models that are quadratic in the revenue partially alleviate this problem. Some researchers also included quadratic risk terms in the objective function in order to achieve interior solutions. None of these methods results in exact calibration. What is ultimately needed for this purpose is activity-specific cost or production functions. But, largely due to data limitations, such functions cannot be easily estimated.

The positive mathematical programming (PMP) approach proposed by Howitt (1991) overcomes this problem common with most linear programming models. Models based on the method have been used in a variety of studies (Oamek 1993, Rosen and Sexton 1993, Bauer 1988). In the PMP approach, output per acre, that is yield, is assumed to be quadratic in land input and Leontief in the other inputs. The resulting linear marginal costs represent increasing cost per acre as more acres are allocated to a specific activity. The PMP approach achieves exact calibration by choosing the parameters of the activity-specific cost functions such that the marginal cost of an activity equals its marginal revenue at exactly the observed base year equilibrium. The parameters are calculated using the base year data and solving the following problem:

Maximize:

$$\max_{X_{crig}} Z = \sum_{c} (a_c + 0.5 b_c Q_c) \cdot Q_c - \sum_{c} \sum_{r} \sum_{i} \sum_{g} AC_{crig} \cdot X_{crig} \tag{9}$$

Subject to:

$$\sum_{c} \sum_{g} X_{crig} \leq LAND_{ri} \tag{10}$$

$$X_{crig} \leq X^0_{crig} + 0.000001 \tag{11}$$

where, X^0 is the base year acreage harvested, 0.000001 is a perturbation, and all the other parameters and variables are as previously defined. The objective function is defined as the area under the demand curves minus cost of production. AC is the observed average cost per acre. To simplify the discussion, the regional price differences, deficiency payments, and deficiency payments provisions are ignored.

As equation 9 is being maximized, the activities begin to bind at their respective constraints (equation 11) in the order of from most profitable to least profitable. Not all the activities, however, exactly bind equation 11. Because of the small perturbation on equation 11, the binding activities use slightly more of the allocatable but constrained land resource than they actually use in the base year. As a result, slightly fewer acres are available for the marginal crops, and these marginal crops then bind the land constraints given by equation 10 before they can bind equation 11. At the solution, there are as many binding constraints as there are activities, and each activity level is exactly equal to its base year level by design.

The fact that all the activities, except the marginal ones, bind equation 11 suggests that there are positive economic profits associated with these activities and that, at the equilibrium, the average cost of production is less than the marginal revenue or the marginal cost. The difference is captured by the dual value, say λ, for the binding activity specific constraints of equation 11. The dual values are then used to derive the parameters of the activity specific cost functions. This is accomplished using the following relationships.

For a single crop let,

$$\textit{Total Cost: } TC=dX+eX^2 \qquad \textit{Marginal Cost: } MC=d+2eX \qquad \textit{Average Cost: } AC=d+eX$$

At the base year output of X^0, λ is a measure of the difference between marginal cost and average cost, that is,

$$\lambda=(d+2eX^0)-(d+eX^0)$$

Solving for e and d we get,

$$e=\frac{\lambda}{X^0} \quad \textit{and} \quad d=AC-\lambda$$

Per acre cost (AC) consists of 24 factor inputs. Ten of these inputs (seed, nitrogen, phosphate, potash, lime, sulfur, trace minerals, manure, irrigation water, and hired labor) have data on per acre application rates and regional prices. The cost data on the other 14 inputs (herbicide, fungicide, defoliant, insecticide, drying/ginning, custom application, fuel and electricity, repairs, technical services, taxes and insurance, interest, capital replacement, overhead, and family labor) are in terms of per acre expenditures. AC is calculated as follows:

$$AC_{crig}=\sum_m u^m v^m_{crig}+\sum_n Z^n_{crig}$$

where: u is the per unit factor price, v is the input application rate per acre, m is an index for the factor inputs with application rates, z is the factor cost per acre, and n is an index for the factor inputs with per acre expenditure data.

To summarize: the model defined by equations 9-11 is solved and λ's are estimated. GAMS steps are in the appendix section "Linear Model Stage." The cost function parameters are calculated and incorporated into equation 1. The problem defined by equations 1-8 is solved and the activities calibrate exactly to their observed base year levels. The GAMS steps are shown in the "Positive Mathematical Programming Model Stage" section in the appendix.

The calibration technique used here is not unique to the PMP approach. Similar techniques have been used in calibrating quadratic programming models (Weins, 1976) and Computable General Equilibrium models (Derviş, 1982).

A small adjustment to the cost function coefficients is made in the case of activities with zero λ value and activities with unreasonably large acreage supply elasticity.

The value of λ represents the economic profit from an activity. It equals total revenue per acre minus per acre explicit costs and opportunity cost of binding land constraint. The opportunity cost, or the dual value, for the land constraint in a region is equal to the net revenue per acre of the marginal activity in that region. There is only one marginal activity per region. A marginal activity, therefore, has zero economic profit, that is, its $\lambda = 0$. Consequently, the cost function associated with a marginal activity has a zero slope and, therefore, a perfectly elastic acreage-supply response. With perfectly elastic supply, marginal activities can fluctuate extensively under small changes in profit conditions. This is also true for activities that show very small economic profit and, therefore, a very small λ value, which then result in a very large acreage supply elasticity.

One possible remedy is to assign an empirically estimated, or arbitrarily determined, supply elasticity for these activities, and recalibrate the parameters of the cost functions. The recalibration steps are as follows:

Given the marginal cost equation above, the corresponding acreage supply elasticity, η, evaluated at the base year equilibrium-level acreage allocation and price is:

$$\eta = \frac{dX}{MC} \cdot \frac{MC}{X^0}$$

The first term is the inverse of the MC equation slope. Therefore,

$$\eta = \frac{1}{2e} \cdot \frac{MC}{X^0}.$$

Using the fact that at the equilibrium $MC = MR = P^0$, and solving the above equation for e we get:

$$e=\frac{P^0}{2\eta X^0}$$

This expression is substituted into the MC equation and d is obtained.

$$d=MC-2eX^0.$$

Note that MC = AC + λ, and, therefore,

$$d=AC+\lambda-2eX^0$$

There are no empirical supply elasticity estimates in the desired detail. Therefore, an arbitrary supply elasticity value of 2 is assigned to the marginal activities and activities with supply elasticity greater than 2. The cost-function coefficients are recalibrated to assure that, when evaluated at equilibrium, supply elasticity for these activities equals 2. The GAMS programming of these steps is in the appendix section "Marginal Activity or Activity with Supply Elasticity > 2."

Market Equilibrium Under Government Intervention

Farm policies have their strongest influence on the agricultural markets via the Deficiency Payment Program and its provisions. It is this aspect of the crop income support program that is modeled here.

A farmer who is planning to cultivate one of the supported crops can either forgo deficiency payments, and just respond to the market price for the crop, or participate in the Deficiency Payment Program and respond to the target price for the crop in deciding how many acres to allocate. The first-order conditions for profit maximization for each option are shown below:

$$(12)\quad C_N'(Q_N)=P(Q)$$

$$(13)\quad C_P'(Q_P)=P(Q)+[TP-P(Q)],\ or$$

$$(13')\quad C_P'(Q_P)=TP$$

Where Q is aggregate crop output and it is the sum of Q_N, output from non-participant, and Q_P, the output from participant, C′ is marginal cost, TP is the target price, and P(Q) is the endogenously determined market price. Recall that, P(Q) = a - bQ in the model.

The problem facing the modeler is how to simulate the above first-order conditions in a programming model. An obvious approach may be to add deficiency payments to the objective function, as shown in the second term of equation 1. Incorporating a policy maximand into the objective function, however, destroys simulation of the free-market equilibrium in that the policy

maximand and the market maximand do not coincide. To see this, consider the following simple problem where there is only one crop, it is cultivated as dryland, the activity is in and/or out of its commodity program, the region constitutes the entire market, and all the resource and institutional constraints are assumed away for sake of simplicity.

$$(14) \quad \underset{X_g}{Max}\ \Pi = \int_0^Q P(U)dU + [TP - P(Q)] \cdot Q_P - \sum_g (C_g \cdot Q_g)$$

The first term represents the area under the demand curve, where U is the constant of integration, the term in the brackets defines the endogenously determined deficiency payment, and the term under the summation sign represents activity specific cost functions which, for simplicity, are expressed symbolically rather than in their quadratic form.

The first-order conditions from equation 14 are:

$$(15) \quad C_N'(Q_N) = P(Q) - P'(Q) \cdot Q_P$$

$$(16) \quad C_P'(Q_P) = TP - P'(Q) \cdot Q_P$$

These conditions differ from the correct ones, that is, equations 12 and 13′, by the appearance of a second term to the right of the minus signs. If the deficiency payment is expressed as in equation 1, then the model solution will not correspond to the market equilibrium. (We thank Arun Malik for formally stating the problem defined by equations 12-16.)

A solution to this problem is to treat P(Q), inside the brackets in equation 14, as a constant and solve the problem. Take the P(Q) from the solution and make it the new constant price, and solve the problem again. Iterate the value of P(Q) in this fashion until convergence occurs. Convergence is achieved, usually, after five iterations. A condition in the iteration procedure ensures that deficiency payments are set to zero if the endogenously determined market price exceeds the target price. The GAMS programming of the iteration steps are shown in the appendix section "Commands to Iterate over Market Price."

Maximizing the objective function is tantamount to solving the competitive equilibrium problem. A 1-year solution produces the equilibrium levels for national crop prices and acreage harvested under an activity that is specific as to crop, participation status, irrigation practice, and region. Other variables of interest can be calculated from the solution, such as regional crop prices, output quantities, factor use, and Government program outlays. The model can be used to conduct many different types of policy and market scenarios by manipulating the various constraints and parameters.

The model is based on 1990 data. The data sources and steps used in preparing the data for the model are discussed in Quiroga, Konyar, and McCormick, 1993. The USARM is written in General Algebraic Modeling System (GAMS) language

(Brooke, Kendrick, and Meeraus, 1988). It is solved using MINOS optimization subroutine. MINOS is a nonlinear programming algorithm which uses a reduced gradient method especially designed for solving large-scale problems with non-linearities in the objective function and/or constraints (Murtagh and Saunders, 1987). Currently, the minimum computer environment required for the model calibration and policy simulations is a DOS-based personal computer with a 386 memory chip. The full model written in GAMS is shown in the appendix.

References

Bauer, S. and H. Kasnakoğlu. "Nonlinear Programming Models for Sector Policy Analysis," Second International Conference on Economic Modeling, London, March 1988.

Brooke, A., D. Kendrick, and A. Meeraus. *GAMS: A User's Guide*. The Scientific Press, San Francisco, 1988.

Boyd, R., K. Konyar, and N. Uri. "Measuring Aggregate Impacts: Case of the Conservation Reserve Program," *Agricultural Systems*, 38(1992):35-60.

Crutchfield, S. "Agriculture's Effects on Water Quality," *Agricultural Food and Policy Review*, AER-620, U.S. Dept. of Agr., Econ. Res. Serv., November 1989.

Derviş, K., J. De Melo, and S. Robinson. *General Equilibrium Models for Development Policy*. Cambridge University Press, Cambridge 1982.

Evans, S., and J. M. Price. "Income and Price Support Programs," *Agricultural Food and Policy Review*, AER-620, U.S. Dept. of Agr., Econ. Res. Serv., November 1989.

Ervin, D., and others. *Conservation and Environmental Issues in Agriculture: An Economic Evaluation of Policy Options*. Staff Report AGES9134, U.S. Dept. of Agr., Econ. Res. Serv., July 1991.

Green, R. *Program Provisions for Program Crops: A Data Base for 1961-1990*. Staff Report AGES 9010, U.S. Dept. of Agr., Econ. Res. Serv., March 1990.

Green, R., and H. Baumes. "Supply Control Programs for Agriculture," *Agricultural Food and Policy Review*, AER-620, U.S. Dept. of Agr., Econ. Res. Serv., November 1989.

Howitt, R. "Positive Mathematical Programming," working paper No. 91-9, Department of Agricultural Economics, University of California, Davis, 1991.

Konyar, K., and I. McCormick. "Farm Policy Options for Agrichemical Reduction: A National/Regional Analysis," paper presented at the American Agricultural Economics Association Meetings, Vancouver, Canada, August 1990.

Langley, S., and H. Baumes. "Evolution of U.S. Agricultural Policy in the 80's," *Agricultural Food and Policy Review*, AER-620, U.S. Dept. of Agr., Econ. Res. Serv., November 1989.

Murtagh, B., and M. Saunders. "Large Scale Linearly Constrained Optimization," *Mathematical Programming*, 14(1987):41-72.

Oamek, G., and S. R. Johnson. "Economic and Environmental Impacts of a Large Scale Water Transfer in the Colorado River Basin," *Western Journal of Agricultural Economics*, forthcoming, 1993.

Quiroga R., K. Konyar, and I. McCormick. *The U.S. Agricultural Resources Model: Data Construction and Updating Procedures*. Staff Report AGES9304, U.S. Dept. of Agr., Econ. Res. Serv., April 1993.

Reichelderfer, K. "Environmental Protection and Agricultural Support: Are Trade-offs Necessary?" in *Agricultural Policies in a New Decade*, K. Allen, ed., Annual Policy Review, Resources for the Future and the National Planning Association, Washington, DC, 1990.

Reichelderfer, K. *Do USDA Farm Program Participants Contribute to Soil Erosion?* AER-532, U.S. Dept. of Agr., Econ. Res. Serv., April 1985.

Ribaudo, M., K. Konyar, and T. Osborn. "Regional Economic Impacts of Wetlands Reserve Program," paper presented at the American Agricultural Economics Association Meetings, Manhattan, KS, August 1991.

Ribaudo, M. *Water Quality Benefits from the Conservation Reserve Program.* AER-606, U.S. Dept. of Agr., Econ. Res. Serv., February 1989.

Robinson, S., M. Kilkenny, and K. Hanson. *The USDA/ERS Computable General Equilibrium (CGE) Model of the United States*. Staff Report AGES 9049, U.S. Dept. of Agr., Econ. Res. Serv., June 1990.

Rosen, M., and R. Sexton. "Irrigation Districts and Water Markets: An Application of Cooperative Decision-Making Theory," *Land Economics*, 69(1993):39-53.

Weins, T.B. "Peasant Risk Aversion and Allocation Behavior: A Quadratic Programming Experiment," *American Journal of Agricultural Economics*, 58(1976):629-635.

U.S. Department of Agriculture. *History of Agricultural Price-Support Programs, 1933-1984*. AIB-485, Econ. Res. Serv., December 1984.

U.S. Department of Agriculture. "Commodity Program Perspectives," *Agricultural Policy Review*, AER-530, U.S. Dept. of Agr., Econ. Res. Serv., July 1985.

Appendix: U.S. Agricultural Resources Model Code Written in GAMS

```
$ TITLE U.S. AGRICULTURAL RESOURCES MODEL (USARM90)
*###########################################################################
*## Department of Economics, California State University, San Bernardino
*## and Resources and Technology Division, ERS/USDA
*## Written by Kazim Konyar (11/17/92).  Telephone: (909) 880-5514
*## This model contains 9 crops and CRP, in 12 regions.  Data version 1990
*###########################################################################

$ OFFSYMXREF OFFSYMLIST
$ MAXCOL 120
 OPTIONS LIMCOL=0, LIMROW=0, RESLIM=50000, NLP=MINOS5;

*###############
*## Declare sets
*###############

 SETS

  CROP   9 CROPS AND CRP

        /BAR   Barley
         COR   Corn
         COT   Cotton
         HAY   Hay
         OAT   Oats
         RIC   Rice
         SOR   Sorghum
         SOY   Soybeans
         WHE   Wheat
         CRP   Conservation Reserve Program/

  Z      12 REGIONS

        /R-AP  Appalachian
         R-CB  Corn Belt
         R-DS  Delta States
         R-LP  Southern Pacific
         R-LS  Lake States
         R-NE  North East
         R-NM  Northern Mountain
         R-NP  Northern Plains
         R-SE  South East
         R-SM  Southern Mountain
         R-SP  Southern Plains
         R-UP  Northern Pacific/

 PART    COMMODITY PROGRAM PARTICIPATION STATUS

        /P     Participating
         N     Not participating/

 IRR     IRRIGATION PRACTICE

        /I     Irrigated
         D     Dryland  /

*##################
*## Declare subsets
*##################

 R(Z)    12 REGIONS

        /R-AP, R-CB, R-DS, R-LP, R-LS, R-NE
         R-NM, R-NP, R-SE, R-SM, R-SP, R-UP/
```

```
 BAROAT(CROP)  BARLEY AND OATS - INTERCHANGEABLE BASE ACRES

       /BAR, OAT/


 CORSOR(CROP)  CORN AND SORGHUM - INTERCHANGEABLE BASE ACRES

       /COR, SOR/


 REST(CROP)     REMAINING CROPS WITH NONINTERCHANGEABLE BASE ACRES

       /COT,  RIC,  WHE/

*########################################
*## Read production, price, and cost data
*########################################
$INCLUDE USARM90.DAT

*####################
*### Data definitions
*####################

* ACRE            : Acres harvested in the base year
* ARP             : Deficiency Payment Program base reduction rate
* BASE            : Farmers' base acreage for program crops
* FAIL            : Ratio of planted to harvested acres
* DFUEL           : Dry fuel costs
* IFUEL           : Irrigated fuel costs
* FUNG            : Fungicides and defoliant cost
* HERB            : Herbicides cost
* INSC            : Insecticides cost
* KREPL           : Capital replacement
* LABP            : Labor price
* LABQ            : Labor application rate
* LOAN            : Regional loan rate
* MAXACRE         : Historical maximum acreage harvested
* NITP            : Nitrogen price
* NITQ            : Nitrogen application rate
* NMPRIC          : National market price
* OTHERVC         : Other variable cost of production, net of land rents
* PHOP            : Phosphate price
* PHOQ            : Phosphate application rate
* PRG             : 1 if participant, 0 if nonparticipant
* PRGYLD          : Program yield used in calculating program payments
* PURC            : Percentage of total water used that is purchased
* RENT            : Crop specific land rents
* RMPRIC          : Regional market price
* TREE            : Acreage put into trees by the CRP participants
* WATP            : Water cost (weighted average of ground and surface water)
* WATQ            : Water application rate
* YIELD           : Actual base year yield, 1 if CRP

*###########################################
*## Declare and define commodity demand data
*###########################################

* MPRICE          : Base year national market price
* DEFPAY          : Base year deficiency payment rate
* TARGET          : Base year target price
* ELAS            : Aggregate own price elasticity of demand
* PRICET-1        : Market price in the previous iteration
```

```
TABLE DEMAND(CROP,*) COMMODITY DEMAND DATA

              MPRICE        DEFPAY        TARGET        ELAS        PRICET-1

BAR            2.140         0.220          2.36        -0.55          2.140
COR            2.280         0.470          2.75        -0.32          2.280
COT            0.664         0.066          0.73        -0.20          0.664
HAY           83.200         0.000          0.00        -0.90         83.200
OAT            1.140         0.310          1.45        -1.04          1.140
RIC            6.500         4.210         10.71        -0.09          6.500
SOR            2.120         0.490          2.61        -1.39          2.120
SOY            5.750         0.000          0.00        -1.13          5.750
WHE            2.610         1.390          4.00        -0.48          2.610
CRP            0.000         0.000          0.00        -1.00          0.000
 ;

*###########################################
*## Declare and define additional CRP data
*###########################################

 TABLE  CRPCB(Z, CROP)  CROP SPECIFIC BASE ACRES RETIRED UNDER CRP

            BAR        COR        COT        RIC        WHE        SOR        OAT

R-AP     13.604    221.531     17.498      0.000    204.524     62.524      4.911
R-CB      4.742   1738.027      0.245      0.072    605.235    161.651    142.543
R-DS      0.039     27.750     48.386     12.640    218.666    109.768      9.306
R-LP     67.311      0.783      0.360      0.000     24.025      0.051      1.315
R-LS    236.368    705.903      0.000      0.000    426.468      0.360    258.770
R-NE      3.245     42.215      0.000      0.000      9.595      0.284     18.237
R-NM    965.245     10.137      0.000      0.000   1346.432      0.511     63.171
R-NP    905.494    718.562      0.000      0.000   3319.155    870.256    667.504
R-SE     11.141    201.134     44.475      0.000    361.718     63.337     43.654
R-SM    119.506     32.687     19.754      0.000   1139.316    305.483     14.901
R-SP     26.867     78.401   1173.814      0.000   1962.247    784.846     58.843
R-UP    362.861      3.100      0.000      0.000    658.398      0.018      8.051
 ;
*#####################
*## Declare parameters
*#####################

 PARAMETERS
   ARP(PART,IRR,CROP,R)              Deficiency Payment Program reduction rate
   ARPIN(PART,IRR,CROP,R)            Inverse of ARP
   DEFPAY(CROP)                      Deficiency payment
   AC(PART,IRR,CROP,R)               Average cost per acre
   ;

*####################
*## Define parameters
*####################

 DEFPAY(CROP) = ((DEMAND(CROP,"TARGET") - DEMAND(CROP,"PRICET-1")) $
               (DEMAND(CROP,"TARGET") GT DEMAND(CROP,"PRICET-1")));

 AC(PART,IRR,CROP,R) =
 (PP(PART,IRR,CROP,R,"NITP") * PP(PART,IRR,CROP,R,"NITQ")) + (PP(PART,IRR,CROP,R,"PHOP") *
  PP(PART,IRR,CROP,R,"PHOQ")) + (PP(PART,IRR,CROP,R,"WATP") * PP(PART,IRR,CROP,R,"WATQ")) +
 (PP(PART,IRR,CROP,R,"LABP") * PP(PART,IRR,CROP,R,"LABQ")) + PP(PART,IRR,CROP,R,"HERB") +
  PP(PART,IRR,CROP,R,"INSC") + PP(PART,IRR,CROP,R,"FUNG") + PP(PART,IRR,CROP,R,"DFUEL") +
  PP(PART,IRR,CROP,R,"IFUEL") + PP(PART,IRR,CROP,R,"KREPL") + PP(PART,IRR,CROP,R,"OTHERVC");

 ARP(PART,IRR,CROP,R) $ (PP(PART,IRR,CROP,R,"PRG") EQ 1) = PP(PART,IRR,CROP,R,"ARP");

 ARPIN(PART,IRR,CROP,R) = 1/(1-ARP(PART,IRR,CROP,R));

*## Effective regional market price is the maximum of regional market price or the loan rate
```

```
 PP(PART,IRR,CROP,R,"RMPRIC") $ (PP(PART,IRR,CROP,R,"RMPRIC") LE PP(PART,IRR,CROP,R,"LOAN"))
     = PP(PART,IRR,CROP,R,"LOAN");

*############################################################
*##  Linear Model Stage: Calculate dual values of activities
*############################################################

*################################################################
*## For Linear Model Stage "*" out the following $ONTEXT command
*## For PMP model stage activate the following $ONTEXT command
$ONTEXT
*################################################################

*##################################
*## Declare Linear Model variables
*##################################

 VARIABLES
   LINOBJ                             Linear objective function to be maximized
   PSUPPLY(CROP)                      Aggregate quantity supplied by participants
   TSUPPLY(CROP)                      Aggregate quantity supplied by all farms
   XACRE(PART,IRR,CROP,R)             Acreage activity Levels

 POSITIVE VARIABLE XACRE, PSUPPLY;

*##################################
*## Declare Linear Model equations
*##################################

 EQUATIONS
     LINOBJEQ                         Linear objective function
     PSUPPLYEQ(CROP)                  Aggregate quantity supplied by the participants
     TSUPPLYEQ(CROP)                  Aggregate quantity supplied
     DRYLAND(R)                       Dryland constraints
     IRRLAND(R)                       Irrigated land constraints;

*#################################
*## Define Linear Model equations
*#################################

 PSUPPLYEQ(CROP)..SUM((IRR,R), XACRE("P",IRR,CROP,R) *
   PP("P",IRR,CROP,R,"PRGYLD")*PP("P",IRR,CROP,R,"FAIL")) =E= PSUPPLY(CROP);

 TSUPPLYEQ(CROP).. SUM((PART,IRR,R),PP(PART,IRR,CROP,R,"YIELD") * XACRE(PART,IRR,CROP,R))
   =E= TSUPPLY(CROP);

 DRYLAND(R).. SUM((PART,CROP), (XACRE(PART,"D",CROP,R) * ARPIN(PART,"D",CROP,R))
   $ PP(PART,"D",CROP,R,"ACRE")) =L=
   SUM((PART,CROP), PP(PART,"D",CROP,R,"ACRE") * ARPIN(PART,"D",CROP,R));

 IRRLAND(R).. SUM((PART,CROP), (XACRE(PART,"I",CROP,R) * ARPIN(PART,"I",CROP,R))
  $ PP(PART,"I",CROP,R,"ACRE")) =L=
  SUM((PART,CROP), PP(PART,"I",CROP,R,"ACRE") * ARPIN(PART,"I",CROP,R));

 LINOBJEQ.. LINOBJ =E=
  SUM(CROP, DEMAND(CROP,"MPRICE") * TSUPPLY(CROP)) + SUM(CROP, (DEMAND(CROP,"DEFPAY")
  * PSUPPLY(CROP)))
  - SUM((PART,IRR,CROP,R),AC(PART,IRR,CROP,R) * XACRE(PART,IRR,CROP,R))
  + SUM((PART,IRR,CROP,R), (PP(PART,IRR,CROP,R,"RMPRIC") - PP(PART,IRR,CROP,R,"NMPRIC"))
  * XACRE(PART,IRR,CROP,R) * PP(PART,IRR,CROP,R,"YIELD"));

*###################################
*## Activity specific constraints
*###################################
  XACRE.UP(PART,IRR, CROP,R) = PP(PART,IRR, CROP,R,"ACRE") * 1.000001;

*################
*## Initial Values
*################
```

```
 XACRE.L(PART,IRR, CROP,R) = PP(PART,IRR, CROP,R,"ACRE");

*##########################
*## Declare model and solve
*##########################

 MODEL
  USARMLIN BASE RUN / ALL /;
   OPTION ITERLIM = 10000;
   SOLVE USARMLIN USING DNLP MAXIMIZING LINOBJ;

 DISPLAY XACRE.M;
*#############################################################################
*## XACRE.M is a table of dual values of activity constraints.  Extract XACRE.M
*## from the output file and save it as an ASCII file under USARM90.PMP
*#############################################################################

*######################
*## End of linear model
*######################

*####################################################################
*## For the Linear Model activate the  $ONTEXT command and "*" out the
*## $OFFTEXT command and for the PMP model do the opposite
*$ ONTEXT
$ OFFTEXT
*####################################################################

*######################################################
*### Positive Mathematical Programming model (PMP) stage
*######################################################

*###########################################
*## Read dual values of activity constraints
*###########################################
$INCLUDE USARM90.PMP

*#########################
*## Declare PMP parameters
*#########################

 PARAMETERS
   ALPHA(CROP)                         Intercept of demand equation
   ARPFACTOR                           A policy parameter to change ARP
   BASEFACTOR                          A policy parameter to change base
   BETA(CROP)                          Slope of demand equation
   CRPBASE(R)                          Base reduced by CRP participants
   CRPRATE(R)                          Base reduction ratio by CRP farms
   CRPCBRATE(R,CRP)                    Crop specific base reduction ratio, CRP farms
   ES(PART,IRR,CROP,R)                 Own price elasticity of supply
   LAMDA(PART,IRR,CROP,R)              Dual values of activity constraints
   DELTA(PART,IRR,CROP,R)              Intercept of cost equation
   EPSI(PART,IRR,CROP,R)               Slope of cost equation
   NEWARP(PART,IRR,CROP,R)             New deficiency payment reduction rate
   NEWARPIN(PART,IRR,CROP,R)           New deficiency payment reduction rate inverse
   QUAN(CROP)                          Aggregate crop production
   YLDFACTOR                           A policy parameter to change yield
   ;

*########################
*## Define PMP parameters
*########################

 ARPFACTOR  = 1.00;
 BASEFACTOR = 1.00;
 YLDFACTOR  = 1.00;

 PP(PART,IRR,CROP,R,"YIELD") $ (PP(PART,IRR,CROP,R,"YIELD") NE 1) =
                                PP(PART,IRR,CROP,R,"YIELD")/YLDFACTOR;
```

```
NEWARP(PART,IRR,CROP,R) = ARP(PART,IRR,CROP,R)*ARPFACTOR;

NEWARPIN(PART,IRR,CROP,R) = 1/(1-NEWARP(PART,IRR,CROP,R));

CRPBASE(R) = SUM(CROP, CRPCB(R,CROP));

CRPRATE(R) $ (SUM(IRR, PP("P",IRR,"CRP",R,"ACRE")) GT 0) =
                 CRPBASE(R) / (SUM(IRR, PP("P",IRR,"CRP",R,"ACRE")));

CRPCBRATE(R,CROP) $ (SUM(IRR, PP("P",IRR,"CRP",R,"ACRE")) GT 0) =
        CRPCB(R,CROP) / (SUM(IRR, PP("P",IRR,"CRP",R,"ACRE")));

QUAN(CROP) = SUM((PART,IRR,R),PP(PART,IRR,CROP,R,"YIELD")*PP(PART,IRR,CROP,R,"ACRE"));

BETA(CROP) = DEMAND(CROP,"MPRICE")/(QUAN(CROP)*DEMAND(CROP,"ELAS"));

ALPHA(CROP) = DEMAND(CROP,"MPRICE") - (BETA(CROP) * QUAN(CROP));

LAMDA(PART,IRR,CROP,R) $ (PP(PART,IRR,CROP,R,"ACRE") GT 0 AND LAMDA(PART,IRR,CROP,R) GT 0)
 = LAMDA(PART,IRR,CROP,R);

EPSI(PART,IRR,CROP,R) $ (PP(PART,IRR,CROP,R,"ACRE") GT 0 AND LAMDA(PART,IRR,CROP,R) GT 0)
 = LAMDA(PART,IRR,CROP,R)/(PP(PART,IRR,CROP,R,"ACRE")*1.000001);

ES(PART,IRR,CROP,R) $ (PP(PART,IRR,CROP,R,"ACRE") GT 0 AND EPSI(PART,IRR,CROP,R) GT 0)
 = PP(PART,IRR,CROP,R,"RMPRIC") / (PP(PART,IRR,CROP,R,"ACRE")*2*EPSI(PART,IRR,CROP,R));

*##############################################################
*## Marginal activity or activity with supply elasticity > 2
*##############################################################

EPSI(PART,IRR,CROP,R) $ (PP(PART,IRR,CROP,R,"ACRE") GT 0 AND
   (LAMDA(PART,IRR,CROP,R) LE 0 OR ES(PART,IRR,CROP,R) GT 2))
 = PP(PART,IRR,CROP,R,"RMPRIC")/(PP(PART,IRR,CROP,R,"ACRE")*2*2.00);

LAMDA(PART,IRR,CROP,R) $ (PP(PART,IRR,CROP,R,"ACRE") GT 0
    AND (LAMDA(PART,IRR,CROP,R) LE 0 OR ES(PART,IRR,CROP,R) GT 2))
 = (2*EPSI(PART,IRR,CROP,R) * PP(PART,IRR,CROP,R,"ACRE")) - LAMDA(PART,IRR,CROP,R);

ES(PART,IRR,CROP,R) $ (PP(PART,IRR,CROP,R,"ACRE") GT 0) =
   PP(PART,IRR,CROP,R,"RMPRIC") / (PP(PART,IRR,CROP,R,"ACRE")*2*EPSI(PART,IRR,CROP,R));

DELTA(PART,IRR,CROP,R) = AC(PART,IRR,CROP,R) - LAMDA(PART,IRR,CROP,R);

*########################
*## Declare PMP variables
*########################

VARIABLES
  PMPOBJ                          PMP objective function to be maximized
  CRPACRE(R)                      Participants' CRP Acreage
  PSUPPLY(CROP)                   Aggregate quantity supplied by participants
  TSUPPLY(CROP)                   Aggregate quantity supplied by all farms
  XACRE(PART,IRR,CROP,R)          Acreage Activity Levels


POSITIVE VARIABLE XACRE, PSUPPLY;

*########################
*## Declare PMP equations
*########################

EQUATIONS
 TSUPPLYEQ(CROP)                  Aggregate quantity supplied equation
 PSUPPLYEQ(CROP)                  Aggregate quantity supplied by participants equation
 DRYLAND(R)                       Regional dryland constraints
 IRRLAND(R)                       Regional irrigated land constraints
 BBAROAT(R)                       Barley Oat base acreage constraints
 BCORSOR(R)                       Corn sorghum base acreage constraints
```

```
 BREST(REST,R)                          Rest of the crops base acreage constraints
 WATER(R)                               Water constraints
 MAXACRES(CROP,R)                       Maximum harvested acreage
 CRPAREA(R)                             Acreage enrolled into CRP by participants
 REGBASE(R)                             Regional base acreage constraints
 PMPOBJEQ                               PMP Objective function equation;

*########################
*## Define PMP equations
*########################

 PSUPPLYEQ(CROP)..SUM((IRR,R) $ PP("P",IRR,CROP,R,"ACRE"),
    XACRE("P",IRR,CROP,R)*PP("P",IRR,CROP,R,"PRGYLD")*PP("P",IRR,CROP,R,"FAIL"))
    =E= PSUPPLY(CROP);

 TSUPPLYEQ(CROP).. SUM((PART,IRR,R),PP(PART,IRR,CROP,R,"YIELD")*
    XACRE(PART,IRR,CROP,R)) =E= TSUPPLY(CROP);

 DRYLAND(R).. SUM((PART,CROP),(XACRE(PART,"D",CROP,R)
  * NEWARPIN(PART,"D",CROP,R)) $ PP(PART,"D",CROP,R,"ACRE")) =L=
    SUM((PART,CROP), PP(PART,"D",CROP,R,"ACRE")*ARPIN(PART,"D",CROP,R));

 IRRLAND(R).. SUM((PART,CROP), (XACRE(PART,"I",CROP,R)
  * NEWARPIN(PART,"I",CROP,R)) $ PP(PART,"I",CROP,R,"ACRE")) =L=
    SUM((PART,CROP), PP(PART,"I",CROP,R,"ACRE")*ARPIN(PART,"I",CROP,R));

 BBAROAT(R).. SUM((IRR,BAROAT), XACRE("P",IRR,BAROAT,R)
  * NEWARPIN("P",IRR,BAROAT,R) * PP("P",IRR,BAROAT,R,"FAIL")) =L=
    (SUM((IRR,BAROAT), PP("P",IRR,BAROAT,R,"BASE")) + SUM(BAROAT, CRPCB(R,BAROAT))
  - SUM(BAROAT, CRPCBRATE(R, BAROAT)) * CRPACRE(R))*BASEFACTOR;

 BCORSOR(R).. SUM((IRR,CORSOR), XACRE("P",IRR,CORSOR,R)
  * NEWARPIN("P",IRR,CORSOR,R) * PP("P",IRR,CORSOR,R,"FAIL")) =L=
    (SUM((IRR,CORSOR), PP("P",IRR,CORSOR,R,"BASE")) + SUM(CORSOR, CRPCB(R,CORSOR))
  - SUM(CORSOR, CRPCBRATE(R, CORSOR)) * CRPACRE(R))*BASEFACTOR;

 BREST(REST,R).. SUM(IRR, XACRE("P",IRR,REST,R)
  * NEWARPIN("P",IRR,REST,R) * PP("P",IRR,REST,R,"FAIL")) =L=
   (SUM(IRR, PP("P",IRR,REST,R,"BASE")) + CRPCB(R,REST) - CRPCBRATE(R, REST)
  * CRPACRE(R))*BASEFACTOR;

 WATER(R).. SUM((PART,CROP), XACRE(PART,"I",CROP,R)
 * PP(PART,"I",CROP,R,"WATQ")) =L=
   (SUM((PART,CROP), PP(PART,"I",CROP,R,"ACRE") * PP(PART,"I",CROP,R,"WATQ"))) * 1.01;

 MAXACRES(CROP,R).. SUM((PART,IRR), XACRE(PART,IRR,CROP,R) $ PP(PART,IRR,CROP,R,"ACRE"))
     $ SUM((PART,IRR), PP(PART,IRR,CROP,R,"MAXACRE") GT 0)
 =L= (SUM((PART,IRR), PP(PART,IRR,CROP,R,"MAXACRE"))) * 1.01;

 CRPAREA(R)..  CRPACRE(R) =E= SUM(IRR, XACRE("P",IRR,"CRP",R));

*##########################################################
*## Additional constraints to accommodate CRP provisions
*##########################################################

 REGBASE(R)..  SUM((IRR,CROP), XACRE("P",IRR,CROP,R) * NEWARPIN("P",IRR,CROP,R)
               * PP("P",IRR,CROP,R,"FAIL")) =L= ((SUM((IRR,CROP), PP("P",IRR,CROP,R,"BASE"))
               + CRPBASE(R)) - (CRPRATE(R)*CRPACRE(R))) * BASEFACTOR;

*##########################
*## PMP Objective Function
*##########################

 PMPOBJEQ.. PMPOBJ =E=
  SUM(CROP, (ALPHA(CROP)  + .5 * BETA(CROP) * TSUPPLY(CROP)) * TSUPPLY(CROP))
   + SUM(CROP, (DEFPAY(CROP) * PSUPPLY(CROP)))
   + SUM((PART,IRR,CROP,R), (PP(PART,IRR,CROP,R,"RMPRIC") - PP(PART,IRR,CROP,R,"NMPRIC"))
   * PP(PART,IRR,CROP,R,"YIELD") * XACRE(PART,IRR,CROP,R))
   - SUM((PART,IRR,CROP,R), (DELTA(PART,IRR,CROP,R) + EPSI(PART,IRR,CROP,R)
```

```
   * XACRE(PART,IRR,CROP,R)) * XACRE(PART,IRR,CROP,R));

*######################
*## Set initial Values
*######################
  XACRE.L(PART,IRR,CROP,R)=PP(PART,IRR,CROP,R,"ACRE");
* XACRE.UP(PART,IRR,"CRP",R)=0;

*###########################
*## Declare model and solve
*###########################

 MODELS
  USARMPMP VERIFICATION OR POLICY RUN / ALL /;

  OPTION ITERLIM = 30000;
  SOLVE USARMPMP USING DNLP MAXIMIZING PMPOBJ;

*#########################################
*## Commands to iterate over Market Price
*#########################################

 SET          ITER     SET TO DRIVE ITERATIONS  /IT-1*IT-10/;

 PARAMETER    DIFFERENCE(CROP)    Convergence price difference
              TEST                Maximum convergence price difference;

 DIFFERENCE(CROP) = ABS(DEMAND(CROP, "PRICET-1") + TSUPPLYEQ.M(CROP));
 DIFFERENCE("HAY") = 0;
 TEST = SMAX(CROP, DIFFERENCE(CROP));
 DISPLAY TSUPPLYEQ.M, DIFFERENCE, DEMAND, TEST;
 LOOP(ITER $ (TEST GT .02),
   DEMAND(CROP, "PRICET-1") = -TSUPPLYEQ.M(CROP);
   DEMAND("CRP", "PRICET-1") = 0;
   DEFPAY(CROP) = ((DEMAND(CROP,"TARGET") - DEMAND(CROP,"PRICET-1")) $
                 (DEMAND(CROP,"TARGET") GT DEMAND(CROP,"PRICET-1")));

 SOLVE USARMPMP USING DNLP MAXIMIZING PMPOBJ;
   DIFFERENCE(CROP) = ABS(DEMAND(CROP, "PRICET-1") + TSUPPLYEQ.M(CROP));
   DIFFERENCE("HAY") = 0;
   TEST = SMAX(CROP, DIFFERENCE(CROP));
   DISPLAY TSUPPLYEQ.M, DIFFERENCE, DEMAND, TEST );

*#########################################################################################
*## For Linear Model activate the $OFFTEXT command and or PMP "*" out the $OFFTEXT command
*$ OFFTEXT
*#########################################################################################

*############
*## End Model
*############
```

☆U.S. Government Printing Office : 1993 - 341-310/81341

UNITED STATES DEPARTMENT OF AGRICULTURE
ECONOMIC RESEARCH SERVICE
WASHINGTON, DC 20005-4788